Available online at www.sciencedirect.com

ScienceDirect

Procedia Materials Science 5 (2014) 311 – 315

Procedia Materials Science

www.elsevier.com/locate/procedia

International Conference on Advances in Manufacturing and Materials Engineering, AMME 2014

Water absorption kinetics and mechanical properties of ultrasonic treated banana fiber reinforced-vinyl ester composites

Rajesh Ghosh[a]*, Dr. A. Ramakrishna[b], G.Reena[c], A. Ravindra[d], Abhishek Verma[e]

[a]*Assistatnt Professor, Mechanical Engg. Dept., GITAM University,*
[b]*Professor, Mechanical Engg. Dept., AUCE, Andhra University,*
[c]*Onsite ETL lead, Tech Mahindra, Singapore,*
[d] *Mechanical Engg. Dept., GITAM University,*
[e]*Mtech student, Mechanical Engg. Dept., GITAM University.*

Abstract

This work focuses on the effect of ultrasonic treatment on the water absorption characteristics and the mechanical properties of woven banana fiber composites. Banana fibers were initially treated with NaOH solution. These were then subjected to ultrasonic treatment while preparing the composites. Similar method was followed earlier to study the effect on water absorption property of the composites which showed encouraging results (Ghosh et al., 2013). A mathematical analysis is done to find the diffusion kinetics. These composites were also tested for their mechanical strengths. The mechanical strengths were found to be better than the composites made in the general procedure. This shows that the composites prepared with ultrasonic treatment have superior properties and can be suitable for wide range of applications.

Selection and peer-review under responsibility of Organizing Committee of AMME 2014

*Keywords:*banana fiber; ultrasonic treatment; water absorption; mechanical strength; composites.

1. Introduction

A lot of research work is done towards the application of plant fiber composites to engineering systems in the household and the automobile sector. With the improvement in the properties of fiber reinforced polymers, these composites are widely accepted for use in structural and non structural applications. Banana plant is abundantly

* Corresponding author. Tel.: +919885238938
*E-mail address:*rajesh_ghosh@yahoo.com

Selection and peer-review under responsibility of Organizing Committee of AMME 2014
doi:10.1016/j.mspro.2014.07.272

grown and these are considered waste after the fruits are ripened. Hence the banana fiber obtained from the plants can be explored as a potential reinforcement. Other plant fibers that play a major role are jute, flax, sisal and pineapple (Brouwer, 2000). It is well known that alkaline treatment cleans the fiber surface off its impurities, modifies the surface structure and increases the fiber surface area. With the increase in surface area, the cellulose microfibrils get exposed, which in turn improved the wettability and impregnation (Kumar and Misra, 2007). The moisture absorption by the fiber composites and its detrimental effect on the mechanical properties are a prime concern especially when these are used for marine applications. Vinyl ester composites shows superior chemical stability in sea water atmosphere (Apicella et al., 1983). Hence in the present work, vinyl ester resin is used to make banana fiber reinforced composites. Composites from enzyme treated fibers have shown better mechanical properties when compared to untreated fiber composites owing to the increased immobilization of the polymer matrix at fiber matrix interface (Karaduman and Onal, 2013).It is reported that banana fiber having high specific strength makes a light weight composite material (Ghosh et al., 2011).

Nomenclature

M_o	initial dry weight of the composite specimen
M_t	measured weight of the composite specimen at time 't'
M_{max}	maximum moisture content at saturation condition
D	coefficient of diffusion
h	thickness of the composite specimen

2. Experimental

2.1. Materials and Fabrication process

Banana fibers were taken as thin bunches and weaved into mats using a wire frame support. These woven mats were then treated with NaOH solution for 4 hours. These mats were then washed with running tap water and then with distilled water to remove any traces of NaOH. These mats were then dried in an oven maintained at 80 ^{o}C for 24 hours. Bisphenol epoxy based vinyl ester resin is obtained from ECMAS Resin Pvt Ltd, India and is used as the matrix material. The detailed fabrication procedure is explained in another journal paper by the same author (Ghosh et al., 2013).

2.2. The sonication process on the fiber mats

The composites specimens were made following the general procedure of hand lay-up technique. Specimens were also made by the sonication processing of the fiber mats in resin. The sonication process is detailed in another paper published earlier (Ghosh et al., 2013). The specimens subjected to different environmental conditions were tested for tensile and flexural tests. The strengths are compared between the following cases.

i. when the fibres are treated with 5% NaOH normally.
ii. when the fibres are treated with 5% NaOH and subjected to sonication process.
iii. when the fibers are treated with 5% NaOH and the composite specimens are immersed in distilled water.
iv. when the fibers are treated with 5% NaOH and subjected to sonication process and the composite specimens are immersed in distilled water.

2.3. Water absorption test

These specimens were first weighed and then immersed in distilled water. Specimens were periodically taken out of the water; the surface is wiped with a tissue paper and weighed in an electronic balance. The water uptake was

plotted against square root of immersion time.
The moisture absorbed 'M' (in %) is calculated using

$$M\% = \frac{M_t - M_o}{M_o} \text{ x } 100 \quad \text{-- (1)}$$

where M_t is the measured weight of the specimen at time t and M_o is the initial dry weight of the specimen.

2.4. Mechanical strengths test

The tensile strength is the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross-section starts to significantly contract. Tensile tests measure the force required to break a polymer composite sample specimen and the extent to which the specimen stretches or elongates to that breaking point.

Tensile tests of the composite specimens were done according to ASTM D638. The tests were carried out in a Hounsfield tensometer - model H20KW. The cross head speed was 1mm/min.

The flexural strength is a mechanical parameter and is defined as the material's ability to resist deformation under load. The flexural test was done according to ASTM D790 in a universal testing machine by UNITED calibration corp. with a cross head speed of 0.5mm/min.

3. Results and discussion

The water absorption into the composite specimen may be considered to be following three different modes. The principal mode being the diffusion of water molecules into the microgaps of the resin, while the other processes being capillary action through the interfacial gap between the fibre and the resin and also through the fiber, and transport of water through the microcracks in the matrix.
The diffusion, in most of the cases, follows the equation

$$\frac{M_t}{M_{max}} = kt^n \text{-- (2)}$$

where M_t is the moisture content at time t, M_{max} is the maximum moisture content at saturation and 'k' and 'n' are constants.
The diffusion coefficient is an important parameter in Fick's law. This can be found out from the following equation

$$M_t = \frac{4 M_{max}}{h} \sqrt{\frac{D t}{\pi}} \text{-- (3)}$$

where M_t , M_{max} and t are as denoted above, and h is the specimen thickness. The diffusion coefficient can be found out by considering the slope of the first portion of the curve between moisture gain and square root of time by the following equation.

$$D = \pi \left(\frac{k h}{4 M_{max}} \right)^2 \text{-- (4)}$$

where 'k' is the initial slope of the plot.
Fig.1 represents the percentage moisture gain plotted against time in hours. The analysis of diffusion mechanism and kinetics can be performed by modifying eqn.(2) as shown below.

$$log \frac{M_t}{M_{max}} = log\ k + n log\ t \quad \text{- (5)}$$

Fig.2 shows the graph plotted against $log \frac{M_t}{M_{max}}$ against log(t). The straight line in Fig.2 shows the fitting of the experimental data to eqn. (3).
The values of 'k' and 'n' resulting from the graph in fig.2 are found to be 0.001355 and 0.5216 respectively.The diffusion coefficient was found to be 4.9558 x 10^{-6} mm^2/sec.

For the case of sonicated specimens immersed in distilled water, the value of 'k' and 'n' resulting from the graph in fig.2 is found to be 0.0006792and 0.4985 respectively.The value of 'n' suggests that the initial diffusion follows Fick's law.The diffusion coefficient was found to be 4.488 x 10^{-6} mm^2/sec.

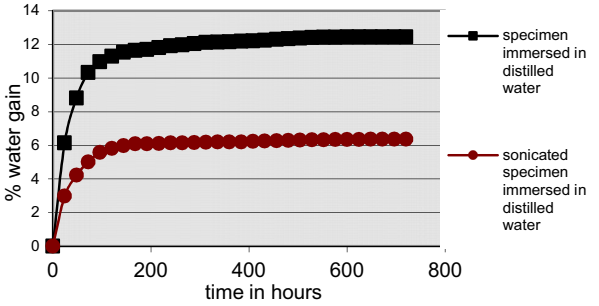

Fig.1: water gain with time

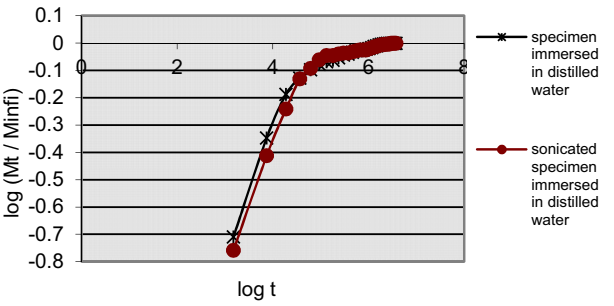

Fig.2: curve fitting for diffusion kinetics

The tensile strength and flexural strength of the composite specimens prepared by different procedures, are plotted as shown in fig.3 and in fig.4 respectively. The tensile strength of the normal dry specimens and strengths of specimens that were water saturated by distilled water are also shown. It can be seen that the composites that were prepared with fibres subjected to sonication process showed improved mechanical strengths.

The tensile strength of the sonicated composite specimen has increased by 4.52% over the specimens prepared in the normal process. There is a heavy reduction in the tensile strength of specimens prepared in the normal process that were immersed in distilled water to the extent of 8.62%. But the tensile strength of the specimens that were prepared by sonication process was marginally reduced by 3.5% in case of composite specimens that were saturated with distilled water.

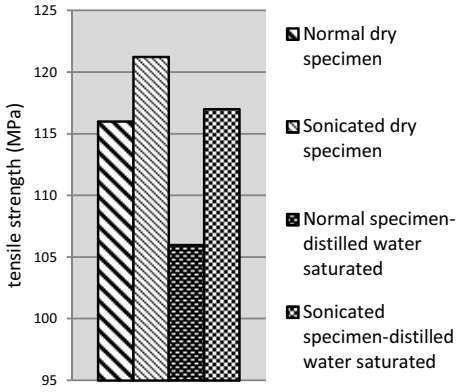

Fig.3: tensile strength of the specimens

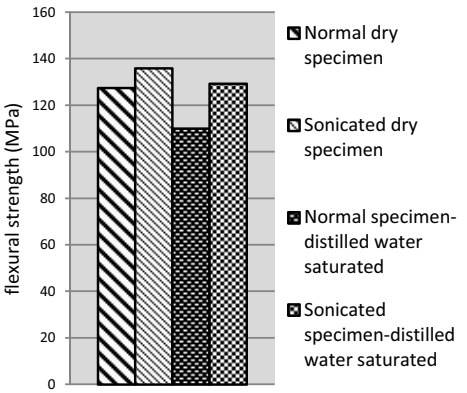

Fig.4: flexural strength of the specimens

The flexural strength of the different composite specimens are plotted and shown in fig.3. The specimen made with sonication process is found to have flexural strength of 6.21% more than the normal specimens. The flexural strength of the normal specimens has reduced heavily by 13.76% in case of distilled water saturated specimens. But marginal reduction in the flexural strength by 4.87% is recorded by the specimens that were made by sonication process and immersed in either distilled water. This can be attributed to the increased wettability and adhesion of the fibres with the resin as the ultrasonic waves force the resin to better penetrate and adhere strongly to the fibres. The micro-gaps in the fiber-matrix interface is eliminated by the sonication process leaving very few voids. Hence the capillary action of water ingress is reduced drastically. Therefore the effect of moisture absorption and the effect of

moisture on the mechanical strengths are reduced.

SEM image of the fractured specimen

Fig.5 and Fig.6 show the SEM images of the fractured specimens.

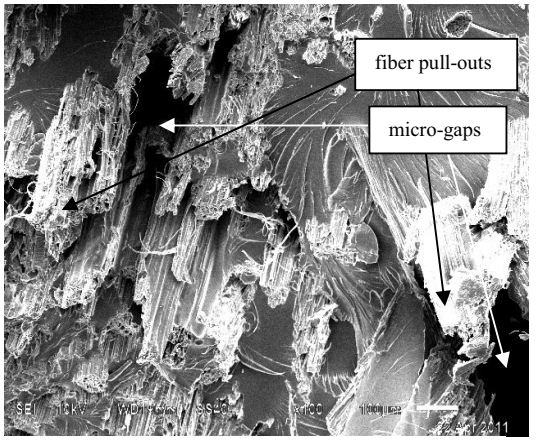

Fig.5 SEM image of fractured specimen of normal reinforcement in resin matrix

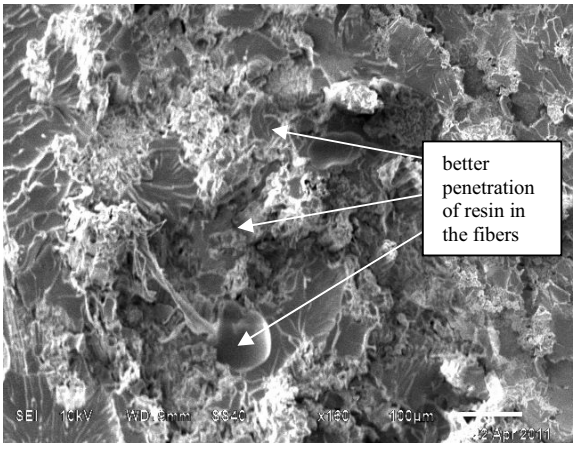

Fig.6 SEM image of fractured specimen of fibres subjected to sonication in resin

The SEM image shows the porous nature of the mercerized fiber. Alkali treatment causes micro-porosity in the fibers. More fiber pull-outs is evident from the SEM image of fractured specimen prepared in the normal method. Micro-gaps are also present that indicates weak adhesion of the resin. Specimens prepared with sonication process show lesser fiber pull-puts and resin penetration is also better. This indicates better adhesion of the resin and the fiber.

Conclusion

The water uptake increases rapidly during the initial stages. The absorption process follows the Fickian diffusion process during the initial stages but later it follows non-fickian diffusion process. Absorption of water causes the deterioration of mechanical properties. In case of sonicated specimens, the mechanical properties of the saturated specimens reduce marginally compared to normal specimens.Fiber pull-out and micro-gaps are more indicating weaker fiber-resin adhesion for normally prepared composite specimens. Sonicated specimens show lesser pull-outs and good penetration of the resin indicating strong bond between fiber and resin.

References

Apicella, A., Migliaresi, C., Nicolais, L., Iaccarino, L., Roccotelli, S., 1983. The water ageing of unsaturated polyester-based composites: influence of resin chemical structure. Composites 14, 387–392.

Brouwer, W.D., 2000. Natural fiber composites in structural components: alternative applications for sisal?, in: Common Fund for Commodities - Alternative Applications for Sisal and Henequen. Polymer Processing Society, Rome,Italy.

Ghosh, R., Ramakrishna, A., Reena, G., Raju, Bh.L.P., 2011. Effect of fibre volume fraction on the tensile strength of Banana fibre reinforced vinyl ester resin composites. Int J AdvEngSciTechnol 4, 89–91.

Ghosh, R., Ramakrishna, A., Reena, G., 2013. Effect of air bubbling and ultrasonic processing on water absorption property of banana fibre-vinylester composites.Journal of Composite Materials.

Karaduman, Y., Onal, L., 2013. Dynamic mechanical and thermal properties of enzyme-treated jute/polyester composites.Journal of Composite Materials 47, 2361–2370.

Kumar, S., Misra, R.K., 2007. Analysis of Banana Fibers Reinforced Low□ density Polyethylene/Poly(Є□ caprolactone) Composites. Soft Materials 4, 1–13.